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ABSTRACT

This guide is intended to assist vocational educators in teaching a three-unit module in metallurgy and heat treating. The module is part of a welding curriculum that has been designed to be totally integrated with Missouri's Vocational Instruction Management System. The basic principles of metallurgy and heat treatment and techniques for identifying and working with metals are covered in the module. The materials included in the module have been formatted for competency-based teaching and testing. All information sheets, transparency masters, job sheets, assignment sheets, and test items are keyed to specific competencies, and a cross-reference table has been included to aid in identifying the parts of the curriculum that relate to specific competencies. Unit tests to evaluate specific competencies have also been provided. (MN)

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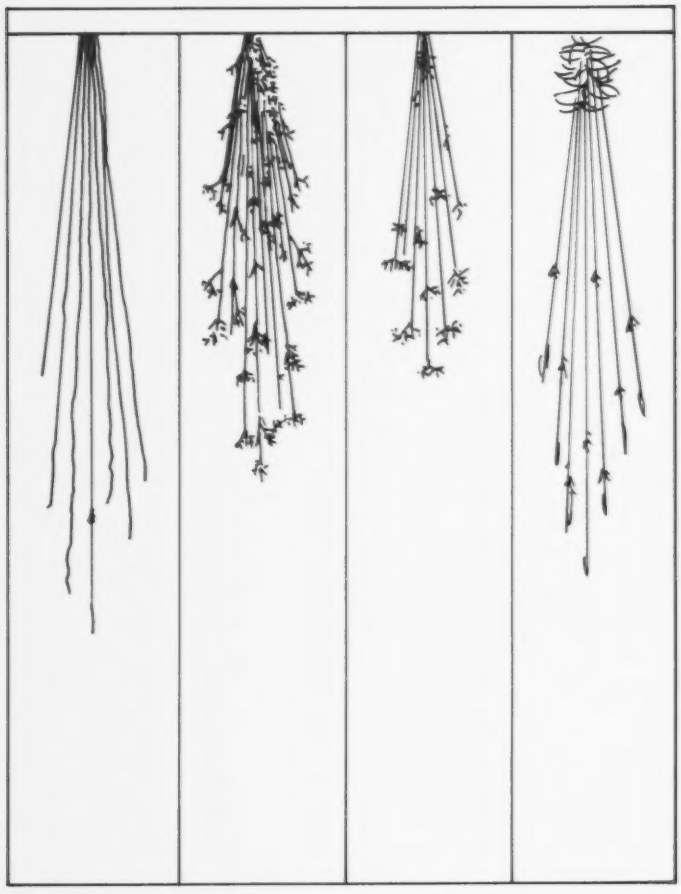
Instructor's Guide

ELDING • Module 7

Metallurgy and Heat Treating



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Module: Metallurgy and Heat Treating

Cross-Reference Table of Instructional Materials

Competency	Instructional Objective	Transparency Master	Handout	Assignment Sheet	Job Sheet	Test Item	Notes
L1					I 1.1, 1.2		
L2	I 1.3-2.3, II 1.1-2.5			I 1.1, 2.1 II 1.1, 1.2	I 1.1, 1.2	I 1-18, II 1-16, 18-48	
L3	III 1.1-2.4	I 2.1		I 1.1, III 1.1		I 19-22, III 1-19	
L4	I 2.4, 2.5	I 2.2	II 2.1	I 2.1		I 23-25, 27, 28	
L5	I 2.6, II 2.6			I 2.1, II 2.1	I 1.1, 1.2	I 26	
L6	II 3.1, 3.2	II 3.1, 3.2		II 3.1	II 3.1	II 17	
L7	III 3.1-3.3			I 1.1, III 3.1			

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MODULE: METALLURGY AND HEAT TREATING

UNIT I: ORIENTATION

UNIT OBJECTIVES

Upon completion of this unit, the student should be able to identify mechanical and physical properties of metals and reasons for proper metal identification. This knowledge will be evidenced by completion of job sheets and the unit test to specified score.

SPECIFIC OBJECTIVES

After completion of the lessons in this unit, the student should be able to:

1.1 Match terms related to basic metals and metallurgy with definitions.

1.2 Identify reasons for proper metal identification.

1.3 Identify alloy characteristics.

1.4 Demonstrate the ability to:

a. Conduct magnet tests.

b. Conduct chisel tests.

2.1 Match mechanical properties of metals with characteristics.

2.2 Distinguish between types of mechanical strengths in metals.

2.3 Match physical properties with characteristics of metals.

2.4 Describe aspects of annealing, hardening and tempering processes.

2.5 Complete statements concerning the effects on ferrous metals by sub-zero temperature range, black-heat range, red-heat range and white-heat range.

2.6 Select appropriate ways of testing metal properties.

MODULE: METALLURGY AND HEAT TREATING

UNIT I: ORIENTATION

CONTENTS OF THIS UNIT

A. Objective sheet

B. References

C. Notes to the instructor

D. Lesson plans

1. Lesson 1: INTRODUCTION TO METALLURGY

   a. Information outline

   b. Assignment sheet

      AS 1.1: Introduction to metallurgy

   c. Job sheets

      JS 1.1: Conduct magnet tests
      JS 1.2: Conduct chisel tests

2. Lesson 2: MECHANICAL AND PHYSICAL PROPERTIES

   a. Information outline

   b. Transparency masters

      TM 2.1: Metal melting points and other temperatures
      TM 2.2: Heating ranges for ferrous metals

   c. Assignment sheet

      AS 2.1: Mechanical and physical properties

E. Unit test

F. Answers to unit test

REFERENCES

A. Book

1. Krar, Oswald and Amand. Technology of Machine Tools. New York: Gregg Division, McGraw-Hill Book Co., 1984.

B. Curriculum guide

1. Fortney, Clarence, and Mike Gregory. Introduction to Welding. Stillwater, Okla.: Mid-America Vocational Curriculum Consortium, Inc., 1984.

NOTES TO THE INSTRUCTOR

A. Suggested student activities

1. Have students harden chisels or temper and bend different metals, both cold and heated.

B. Suggested supplemental materials

1. Welding Supplementary Units. Columbia: Instructional Materials Laboratory, University of Missouri-Columbia, 1988.

MODULE: METALLURGY AND HEAT TREATING

UNIT I: ORIENTATION

LESSON 1: INTRODUCTION TO METALLURGY

I. Terms and definitions

A. AA--Aluminum Association

B. AISI--American Iron and Steel Institute

C. Compatibility--two or more metals that have properties that can readily be welded

D. Extruding--process of forcing a heated metal through a special form to give it shape and length

E. Filler metals--metals added when making a brazed, welded or soldered joint

F. Heat-affected zone--area of parent metal that has not melted, but which is still subject to heat effects. This is where distortion and stress occur.

G. Interpass heating--application of heat to a base metal during a welding process

H. Metallurgy--science of separating metals from their ores and smelting or refining them for use

I. Postheating--application of heat to welding or a weldment after a welding or cutting operation to promote a slower cooling rate and relieve stresses in the base metal and the weldment

J. Preheating--application of heat to a base metal before welding or cutting

K. SAE--Society of Automotive Engineers

L. Strain-hardened--metal that has had its strength increased (with or without minimum thermal treatment)

M. Weldment--assembly of two or more metal parts with welding

II. Metal identification

A. Reasons for proper identification

1. Determines selection of filler metals

2. Determines preheat, interpass or postheat requirements

3. Determines welding processes

4. Determines compatibility of metals

B. Basic categories of metals

1. Ferrous metals contain iron as a major element.

   Examples: cast iron and low, mild, medium and high carbon steels

2. Nonferrous metals contain no iron or extremely small amounts of it.

   Examples: aluminum, copper, zinc, lead, tin, nickel, silver, titanium and gold

III. Alloys and characteristics

A. Alloy--metal formed by melting, fusing or mixing two or more metals together

B. Alloy steels--steels with other metals added to give certain characteristics or properties

   NOTE: Alloys may be ferrous or nonferrous, but alloy steels are always ferrous.

C. Spark--Ferrous metals have definite spark patterns, while nonferrous metals have no spark patterns.

D. Chemical--chemicals or acids applied to metals to cause different reactions

   Examples: A weak solution of nitric acid or copper sulfate applied to stainless steel will remain clear, but will darken when applied to carbon steel.

E. Appearance--general surface appearance, color and presence of oxidation

F. Sound--When struck with a hammer, most metals have a characteristic ring or lack of it. (Steel has a higher-pitched ring than cast iron.)

G. Chisel--When chipped with a chisel, certain metals produce a continuous chip; others break up into small particles; still others cannot be chipped.

   Example: Low-carbon steel chips easily and leaves a continuous chip. Cast iron is not easily chipped and breaks up into small pieces.

INTRODUCTION TO BASIC METALS AND METALLURGY

Match the terms on the right with corresponding definitions.

____ 1.	Science of separating metals from their ores and smelting or refining them for use	a.	AA
____ 2.	Metals added when making a brazed, welded or soldered joint	b.	AISI
____ 3.	Application of heat to a base metal before welding or cutting	c.	Compatibility
____ 4.	Application of heat to a base metal during a welding process	d.	Extruding
____ 5.	Application of heat to welding or a weldment after a welding or cutting operation	e.	Filler metals
____ 6.	Assembly of two or more metal parts with welding	ab.	Heat affected zone
____ 7.	Two or more metals that have properties that can readily be welded	ac.	Interpass heating
____ 8.	American Iron and Steel Institute	ad.	Metallurgy
____ 9.	Society of Automotive Engineers	ae.	Postheating
____ 10.	Process of forcing a heated metal through a special form to give it shape and length	bc.	Preheating
____ 11.	Aluminum Association	bd.	SAE
____ 12.	Metal that has had its strength increased (with or without minimum thermal treatment)	be.	Strain-hardened
____ 13.	Area of parent metal that has not melted, but which is still subject to heat effects	cd.	Weldment

Choose the option which best answers the question or completes the statement.

____ 14. Which is <u>not</u> a reason to properly identify metals?

a. Determines selection of filler metals
b. Determines preheat, interpass or postheat requirements
c. Determine end-product
d. Determines compatibility of metals

____ 15. Which is not an alloy characteristic?

a. A metal formed by melting, fusing or mixing one or more metals together
b. Steels with one or more other metals added; nonferrous metals dominate ferrous ones
c. Ferrous metals contain iron as a major element.
d. Nonferrous metals contain little or no iron.

____ 16. Ferrous metals have definite _____ patterns, while nonferrous metals have none.

a. Spark
b. Sound
c. Chemical
d. Grain

INSTRUCTOR'S NOTE: Completion of this assignment sheet to specified score is the student's partial evaluation for competencies L2, L3 and L7.

ANSWERS TO ASSIGNMENT SHEET 1.1

1. ad
2. e
3. bc (L3)
4. ac (L3)
5. ae (L3)
6. cd
7. c (L2)
8. b
9. bd
10. d
11. a
12. be (L7)
13. ab (L3)
14. c (L2)
15. b (L2)
16. a (L2)

CONDUCT MAGNET TESTS

Equipment:

Safety glasses
Hand-held magnet
Metal samples, as approved by instructor

Procedure:

Evaluation 3 2 1 N

1. Place the first metal sample on a wooden or nonmagnetic work space. — — — —
2. Place the magnet on the metal sample. — — — —
3. Observe whether or not the magnet sticks to the metal sample. Record your findings on Magnet Test Chart. — — — —

Magnet Test Chart

Metal sample #	Magnetic (ferrous)	Nonmagnetic (nonferrous)
a.		
b.		
c.		
d.		
e.		

4. Repeat the procedure for each of the metal samples. — — — —
5. Complete Magnet Test Chart and turn it in to your instructor for evaluation. — — — —
6. As directed by instructor, prepare for next job sheet or clean up area and return tools and materials. — — — —

Average of above evaluations* — — — —

*This average is the student's partial evaluation for competencies L1, L2 and L5.

CONDUCT CHISEL TEST

Equipment:

Safety glasses
Cold chisel
Hammer
Vise
Numbered metal samples, as approved by instructor

Procedure:

Evaluation 3 2 1 N

1. Put on safety glasses and face shield. Secure the first metal sample in a vise. — — — —

2. Select a starting point that will provide a sufficient working distance along the workpiece. Place the chisel at a 30- to 40-degree angle over the workpiece and strike the chisel head firmly with a hammer. — — — —

3. Strike the chisel as many times as required to establish whether it's easy or difficult to chip the metal. Record this information on the chart below. — — — —

Chisel Test Chart

Metal sample #	Degree of chipping difficulty	Size of chips	Appearance of chips	Name of metal
a.				
b.				
c.				
d.				

4. Determine whether the chip or chips are continuous, small particles or if there are no chips at all; record this information on the chart. — — — —

5. Determine whether the chip or chips have smooth or rough edges and record this information on the chart. — — — —

6. Repeat the above procedure for all metal samples approved by the instructor. Complete your Chisel Test Chart and turn it in to instructor for evaluation. — — — —

7. As directed by instructor, prepare for next job sheet or clean up area and return tools and materials. — — — —

Average of above evaluations* — — — —

*This average is the student's final evaluation for L1 and partial evaluation for competencies L2 and L5.

MODULE: METALLURGY AND HEAT TREATING

UNIT I: ORIENTATION

LESSON 2: MECHANICAL AND PHYSICAL PROPERTIES

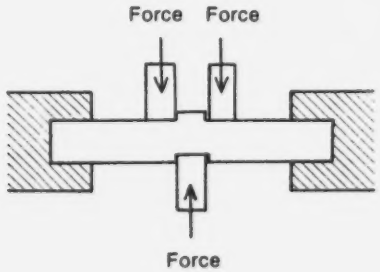
NOTE: The two basic elements of metallurgy are mechanical properties and physical properties. This lesson will discuss these elements in depth.

I. Mechanical properties of metals

- A. Hardness--metal's capacity to resist penetration, abrasion and deformation
- B. Strength--capacity of a metal to resist changing its shape or size when exposed to external forces
- C. Ductility--metal's capacity to be permanently stretched without breaking
- D. Malleability--capacity of a metal to be hammered or rolled into shape without breaking
- E. Brittleness--tendency of certain metals to break or fracture if bent or struck sharply
- F. Elasticity--capacity of a metal to return to its original size and shape when the force that changed it is removed
- G. Plasticity--incapacity of a metal to return to its original size and shape when the force that changed it is removed
- H. Fatigue--tendency of some metals to break or fracture under a repeated or sustained load
- I. Impact resistance--capacity of a metal to absorb the impact of a load applied rapidly without failure
- J. Elongation--flexibility of material measured in a tension test

II. Types of mechanical strengths

- A. Tensile--capacity of a metal to resist being pulled apart
- B. Compressive--capacity of a metal to resist being pushed or crushed together
- C. Shear--capacity of a metal to withstand a sustained load across its cross-section



D. Torsional--capacity of a metal to resist twisting forces

III. Physical properties of metals

A. Density--weight of a given piece of metal in relation to a unit size, such as one cubic foot

NOTE: A cubic coot of aluminum weighs less than a cubic foot of steel, so most steel has a great density than most aluminum.

B. Electrical conductivity--capacity of a metal to conduct electrical current. (For example, copper has a much higher electrical conductivity than steel and is used in many electrical wires.)

C. Thermal conductivity--capacity of a metal to conduct heat. (For example, silver and copper have high thermal conductivity.)

D. Thermal expansion--tendency of metals to expand when heated as expressed in terms of coefficient of expansion

NOTE: Thermal expansion is extremely important in welding because a metal such as aluminum, which has a high coefficient of thermal conductivity, readily spreads heat throughout the workpiece and minimizes distortion at the weld zone. Metals such as stainless steel, which has a low coefficient of thermal conductivity, localize the heat in the weld zone and cause a greater amount of distortion.

E. Melting point--temperature to which a metal must be heated before it will melt (TM 2.1)

IV. Annealing, hardening and tempering

A. Annealing--a heat-treating method which softens metal and improves its machinability. Annealing also relieves internal stresses and strains caused by previous operations, such as forging or rolling.

1. Procedure

a. Set the pyrometer approximately 30F (16.6 C) above the upper critical temperature and start the furnace.

b. Place the part in the furnace. After the required temperature has been reached, allow it to soak for one hour per inch (25.4 mm) of workpiece thickness.

c. Shut off furnace and allow the part to cool slowly in the furnace or remove the part and pack it immediately in lime or ashes, leaving it covered for several hours until cool.

B. Critical point--point at which carbon, which is the chief hardening agent, changes its structure. This produces a hardness that is superior to that of the steel before heating and cooling.

C. Hardening--process in which steel is heated above its critical point and then cooled rapidly. Only medium, high and very high carbon steel can be treated in this way.

1. Once the critical temperature of a steel has been determined, the proper quenching temperature (about 50F {27.7 C} over the upper critical temperature) can be determined.

2. The critical temperature of a steel drops as the carbon content increases up to 0.83%. Although the increase in the carbon content beyond 0.83% will not increase the steel's hardness, it does increase wear resistance considerably.

3. For the steel to be hardened properly, it must be heated uniformly to about 50F (27.7 C) above the critical temperature and held there long enough to allow sufficient carbon to dissolve and form a solid solution for maximum hardness.

4. A steel's critical temperature is also affected by alloying elements such as manganese, nickel, chromium, cobalt and tungsten.

D. Tempering--process of heating a hardened carbon or alloy steel below its lower critical temperature and cooling it by quenching in a liquid or in air.

1. This operation removes many of the stresses and strains set up when the metal was hardened.

2. Tempering imparts toughness to the metal but decreases the hardness and tensile strength.

3. The tempering and drawing temperature is not the same for each type of steel and is affected by the part's required toughness and hardness, as well as the steel's carbon content and alloying elements.

4. Generally, hardness decreases and toughness increases as temperature is increased.

5. As the length of the tempering time is increased for a specific part, the hardness of the metal decreases. On the other hand, if the tempering time is too short, stresses and strains set up by hardening are not totally removed, causing brittleness.

6. The workpiece's cross-sectional size affects tempering time.

7. Tempering time and temperatures for various steels are supplied in the steel manufacturer's handbook and should be followed to obtain the best results.

V. Temperature effects on ferrous metals (TM 2.2)

A. Sub-zero temperature range

1. Range is 0-300F.

2. Almost all metals in this range have a lower impact resistance. The lower the temperature, the lower the impact resistance.

B. Black-heat range

NOTE: All temperatures given in the following color-coded heat ranges are based on steel without carbon content. As carbon content in steel increases, preheating temperatures increase and temperatures above the transformation range decrease.

1. Range is 0-1,000F.

2. Includes the preheating range for welding (about 60-700F)

3. Includes blue brittle range of 300-700F, a range at which peening or working of steels should not be done since metals are more brittle in this range

4. Includes the nitriding range of 950-1,000F, where certain special steels are subjected to ammonia gas for long periods to give them extremely hard skin (metal absorbs nitrogen)

C. Red-heat range

1. Range is 1,000-2,050F.

2. Includes the stress-relieving range (1,120-1,250F), where temperatures are held long enough to relieve locked-up stresses. Then the metal is slowly cooled to produce process annealing.

3. Includes the spheroidizing range (1,250-1,350F), where temperatures are held long enough to produce a softness that usually provides good machinability

4. Includes the transformation range (1,350-1,690), where steels undergo a change in atomic arrangements that radically affects their properties

5. Includes the annealing and normalizing range (1,400-1,750F), where temperatures are held long enough to form austenite, then slowly cooled to produce small grain size, softness and good ductility (flexibility)

6. Includes the carburizing range (1,600-1,810F), where carbon is dissolved into the steel surface in the presence of carburizing compounds or gas mixtures to create hard, high-carbon steel

7. Includes forging range (1,810-2,400), where metals can be mechanically worked or fused together

D. White-heat range

1. Range is 2,050-2,900F.

2. Includes maximum forging temperature at 2400F.

3. Includes a transitional range where forging can no longer be done and burning begins

4. At 2,490-2,550F steel is ruined and cannot be reused unless remelted.

5. Above the burning range and up to 2,900F, steels become liquid.

VI. Ways of testing metal properties

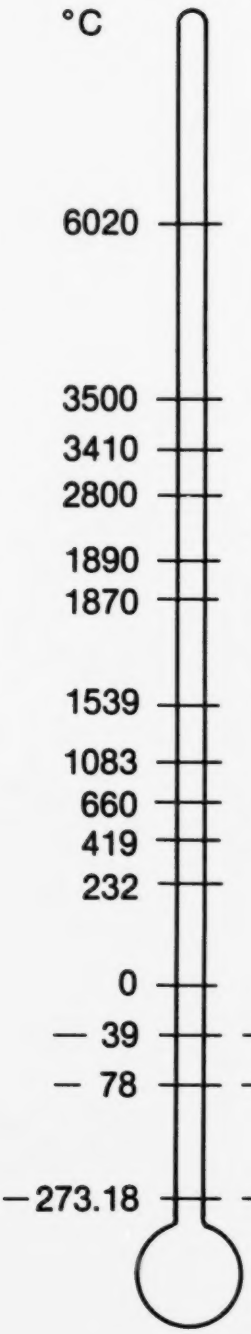
A. Brinell-Rockwell test for hardness

B. Shore's scleroscope test for hardness

C. Hydraulic test for tensile strength and ductility (flexibility)

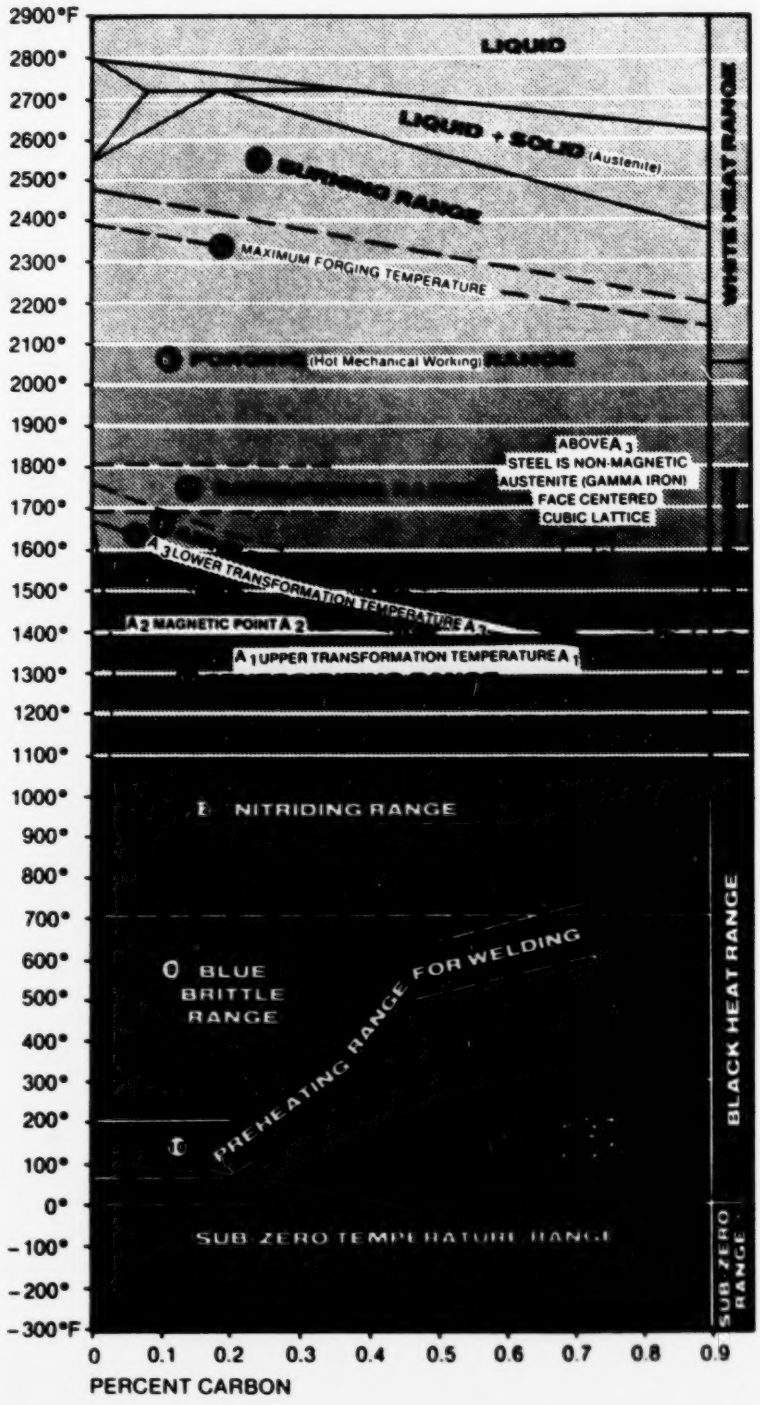
D. Izod-Charpy test for impact resistance

METAL MELTING POINTS AND OTHER TEMPERATURES



°C	°F	
6020	10,900	Welding Arc
3500	6330	Oxyacetylene Flame
3410	6170	Tungsten Melts
2800	5070	Oxyhydrogen Flame
1890	3430	Chromium Melts
1870	3360	Natural Gas Burner
1539	2802	Iron Melts
1083	1981	Copper Melts
660	1220	Aluminum Melts
419	787	Zinc Melts
232	449	Tin Melts
0	32	Ice Melts
— 39	— 38	Mercury Melts
— 78	—110	Dry Ice Vaporizes
—273.18	— 459.72	Absolute Zero

HEATING RANGES FOR FERROUS METALS



MECHANICAL AND PHYSICAL PROPERTIES

Place a T before true statements and an F before false ones.

____ 1. Elongation, elasticity and hardness are physical properties.

____ 2. Density, thermal conductivity and melting point are physical properties.

____ 3. The measure of ductility of material measured in a tension test is called elongation.

____ 4. Strength is the capacity of a metal to resist changing its shape or size when exposed to external forces.

____ 5. Compressive strength is the capacity of a metal to withstand a sustained load across its cross section.

____ 6. Hardness is the capacity of a metal to resist penetration, abrasion and deformation.

____ 7. A welder would test for ductility and tensile strength with a Brinell-Rockwell test.

____ 8. Annealing is a heat-treating operation used to soften metal and to improve its machinability.

____ 9. Hardening is a process in which steel is heated above its critical point and then cooled rapidly.

____ 10. Tempering is the process of heating a hardened carbon or alloy steel below its lower critical temperature and cooling it by quenching in a liquid or in air.

ANSWERS TO ASSIGNMENT SHEET 2.1

1. F (L2)
2. T (L2)
3. T (L2)
4. T (L2)
5. F (L2)
6. T (L2)
7. F (L5)
8. T (L4)
9. T (L4)
10. T (L4)

MODULE: METALLURGY AND HEAT TREATING

UNIT I: ORIENTATION

UNIT TEST

Match mechanical and physical properties of metals with appropriate characteristics.

____ 1.	Capacity of a metal to resist penetration, abrasion and deformation	a.	Brittleness
____ 2.	Capacity of a metal to resist changing its shape or size when exposed to external forces	b.	Density
____ 3.	A metal's capacity to be permanently stretched without breaking	c.	Ductility
____ 4.	Capacity of a metal to be hammered or rolled into shape without breaking	d.	Elasticity
____ 5.	Tendency of certain metals to break or fracture if bent or struck sharply	e.	Electrical conductivity
____ 6.	Capacity of a metal to return to its original size and shape when the force that changed it is removed	ab.	Elongation
____ 7.	Incapacity of a metal to return to its original size and shape when the force that changed it is removed	ac.	Fatigue
____ 8.	Tendency of some metals to break or fracture under a repeated or sustained load	ad.	Hardness
____ 9.	Capacity of a metal to absorb the impact of a load applied rapidly without failure	ae.	Impact resistance
____ 10.	Ductility (flexibility) of material as measured in a tension test	bc.	Malleability
____ 11.	Weight of a given piece of metal in relation to a unit size, such as one cubic foot	bd.	Melting point
____ 12.	Capacity of a metal to conduct electrical current	be.	Plasticity
____ 13.	Capacity of a metal to conduct heat	cd.	Strength
____ 14.	Tendency of metals to expand when heated; expressed in terms of coefficient of expansion	ce.	Thermal conductivity
____ 15.	Temperature to which a metal must be heated before it will melt	de.	Thermal expansion

Choose the option which best answers the question or completes the statement.

___ 16. Which type of mechanical strength is indicated by a metal's capacity to resist being pulled apart?

a. Compressive
b. Shear
c. Tensile
d. Torsional

___ 17. Which type of mechanical strength is indicated by a metal's capacity to withstand a sustained load across its cross section?

a. Compressive
b. Shear
c. Tensile
d. Torsional

___ 18. A metal which resists twisting forces demonstrates ___ strength.

a. Compressive
b. Shear
c. Tensile
d. Torsional

___ 19. Sub-zero range extends from 0F to _____ .

a. -200F
b. -300F
c. -400F
d. -500F

___ 20. Almost all metals in the sub-zero range have a _____ impact resistance. The _____ the temperature, the lower the impact resistance.

a. Higher, higher
b. Higher, lower
c. Lower, lower
d. Lower, higher

___ 21. The black-heat range extends from 0F to _____ .

a. 1000F
b. 850F
c. 500F
d. 450F

___ 22. The black-heat range includes which other welding range?

a. Preheat
b. Blue brittle
c. Nitriding
d. All of the above

___ 23. The red-heat range extends from _____ .

a. 1000F to 1500F
b. 850F to 1500F
c. 1000F to 2050F
d. 1500F to 2050F

___ 24. At which range does steel undergo a change in atomic arrangement?

a. Transformation
b. Spheroidizing
c. Forging
d. Carburizing

___ 25. Which is <u>not</u> true of white-heat range affects on metal?

a. Range extends from 2050F to 2900F
b. Includes maximum forging temperature at 2400F
c. Includes a transitional range where forging can no longer be done and burning begins
d. Includes a burning range from about 2490F to 2550F, a range at which steel is ruined and cannot be used again unless cooled
e. Includes a range above the burning range, up to 2900F, at which steels become liquid

___ 26. Which is <u>not</u> an appropriate way of testing properties of metals?

a. Brinell-Rockwell test for hardness
b. Izod-Charpy test for hardness
c. Shore's scleroscope test for hardness
d. Hydraulic test for tensile strength and ductility

___ 27. Which type of heat treating process softens metal and improves machinability?

a. Annealing
b. Hardening
c. Tempering
d. All of the above

___ 28. Which heat treating process heats a carbon or steel alloy below critical temperature, then cools it in liquid or air?

a. Annealing
b. Hardening
c. Tempering
d. All of the above

NOTE: Completion of this test to specified score is the student's final evaluation for competency L3 and partial evaluation for L2, L4 and L5.

ANSWERS TO UNIT TEST

1. ad (L2)
2. cd (L2)
3. c (L2)
4. bc (L2)
5. a (L2)
6. d (L2)
7. be (L2)
8. ac (L2)
9. ae (L2)
10. ab (L2)
11. b (L2)
12. e (L2)
13. ce (L2)
14. de (L2)
15. bd (L2)
16. c (L2)
17. b (L2)
18. d (L2)
19. b (L3)
20. c (L3)
21. a (L3)
22. d (L3)
23. c (L4)
24. a (L4)
25. d (L4)
26. b (L5)
27. a (L4)
28. c (L4)

MODULE: METALLURGY AND HEAT TREATING

UNIT II: IDENTIFYING METALS

UNIT OBJECTIVES

Upon completion of this unit, the student should be able to identify alloying elements and number classification of metals. The student should also be able to use the spark test to identify metals. This knowledge will be evidenced by completion of the job sheet and unit test to specified score.

SPECIFIC OBJECTIVES

After completion of the lessons in this unit, the student should be able to:

1.1 Match principal alloying agents of steel with characteristics.

1.2 Match metals with ways to identify them by appearance.

1.3 Solve problems concerning systems for identifying steel.

1.4 Complete charts of carbon steel classifications, characteristics and uses.

1.5 Identify alloy steels by classification, characteristics and uses.

1.6 Identify irons by classification, characteristics and uses.

2.1 Select true statements concerning aluminum characteristics and uses.

2.2 Solve problems concerning the AA system of identifying aluminum and aluminum alloys.

2.3 Solve problems concerning the AA temper designation system for aluminum.

2.4 Identify aluminum abbreviations.

2.5 Arrange in order the steps in identifying aluminum.

2.6 Select true statements concerning chemical tests for identifying aluminum alloys.

2.7 Match other nonferrous metals with typical uses.

3.1 Identify equipment requirements for spark testing.

3.2 Conduct spark tests to identify common welding metals.

MODULE: METALLURGY AND HEAT TREATING

UNIT II: IDENTIFYING METALS

CONTENTS OF THIS UNIT

A. Objective sheets

B. References

C. Notes to the instructor

D. Lesson plans

1. Lesson 1: IDENTIFYING FERROUS METALS

   a. Information outline

   b. Assignment sheets

      AS 1.1: Identifying ferrous metals
      AS 1.2: Identify selected metals by appearance, color and corrosion characteristics

2. Lesson 2: IDENTIFYING NONFERROUS METALS

   a. Information outline

   b. Handout

      HO 2.1: Aluminum hardness and tempering designations

   c. Assignment sheet

      AS 2.1: Identifying nonferrous metals

3. Lesson 3: SPARK TESTING

   a. Information outline

   b. Transparency masters

      TM 3.1: Spark test characteristics
      TM 3.2: Spark test characteristics (cont.)

   c. Assignment sheet

      AS 3.1: Spark testing

   d. Job sheet

      JS 3.1: Conduct spark tests

E. Unit test

F. Answers to unit test

REFERENCES

A. Book

1. Krar, Oswald and Amand. Technology of Machine Tools. New York: Gregg Division, McGraw-Hill Book Co., 1984.

B. Curriculum guide

1. Fortney, Clarence, and Mike Gregory. Introduction to Welding. Stillwater, Okla.: Mid-America Vocational Curriculum Consortium, Inc., 1984.

NOTES TO THE INSTRUCTOR

A. Suggested approaches to teaching this unit

1. Use metal identification demonstrations frequently to reinforce learning.

2. Review instructional material often as welding metals are changed.

B. Suggested supplemental materials

1. Welding Supplementary Units. Columbia: Instructional Materials Laboratory, University of Missouri-Columbia, 1988.

MODULE: METALLURGY AND HEAT TREATING

UNIT II: IDENTIFYING METALS

LESSON 1: IDENTIFYING FERROUS METALS

I. Principal alloying agents of steel

A. Chromium--grayish-white, hard metallic element used instead of carbon to make special steels that are less brittle but harder than other steels with the same carbon content

B. Nickel--silvery-white, hard ductile (flexible) metallic element used to make special steels with increased strength, improved ductility and added toughness at low temperatures

C. Molybdenum--silvery-white, hard metallic element used to make special steels that require increased hardness or strength in hot surface applications

D. Vanadium--silvery-white metallic element used to make special steels with added tensile strength

E. Carbon--nonmetallic element added to iron to make steels that are harder and stronger

F. Tungsten--steel-gray, brittle metallic element used to make special hard steels used in tool manufacturing

G. Silicon--hard, brittle nonmetallic element used to make special steels that are hard and brittle

H. Manganese--grayish-white, red-tinged nonmetallic element that is used to make special steels that are hard but less brittle

I. Cobalt--a hard, steel-gray element used to make steels subject to corrosive or high-temperature service

II. Identifying metals by appearance

A. Low-, medium- and high-carbon steel: dark gray when new; will rust with age and rust rapidly when stored outside

B. Manganese steel: dull-cast surface when new; will rust with age or when stored outside

C. Stainless steel: bright, silvery and smooth when new, but some grades rust and others tarnish

D. Cast iron: dull gray with evidence of sand mold; rusts rapidly in almost any environment

E. Wrought iron: light gray and smooth; rusts rapidly in almost any environment

F. Aluminum: silvery-white with a smooth surface; highly rust and corrosion-resistant except when alloyed with certain other elements; weighs much less than iron or steel

G. Copper: reddish-brown with a dull finish; highly subject to tarnishing

H. Nickel: white with a hard finish; has a good resistance to rust and corrosion

III. Systems for identifying steel

A. Principal alloying ingredients are assigned numbers to assist with identification.

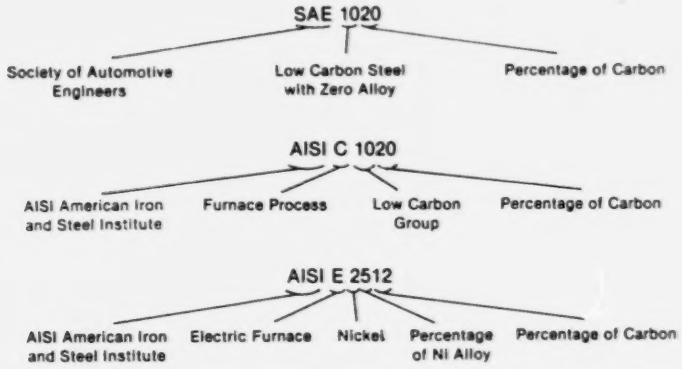
1. Carbon
2. Nickel
3. Nickel-chromium
4. Molybdenum
5. Chromium
6. Chromium-vanadium
7. Tungsten
8. Nickel-chromium-molybdenum
9. Silicon-manganese

B. Processing methods are assigned AISI letters to assist with identification

1. A = Open-hearth alloy steel
2. B = Acid Bessemer carbon steel
3. C = Basic open-hearth carbon steel
4. D = Acid open-hearth carbon steel
5. E = Electric furnace steel

C. The first digit of the number code indicates the type of alloy, while the second digit indicates the percentage of that alloy. The last two digits indicate the percentage of carbon in the steel.

SAE/AISI Designations



D. Color coding on the ends of steel bars or sheets indicates the type of steel.

NOTE: Color coding varies with each manufacturer, so identification requires a guide from the mill that produced the steel. When working with color-coded stock, start from the opposite end of the coloring so the stock can still be quickly identified even after part of it has been used.

E. UNS (Unified Numbering System) is a system used by SAE and ASTM that utilizes a letter prefix with a five-digit number. The letter usually suggesting a general ferrous metal or alloy group.

Ferrous metals

ID letter and no.	General metal or alloy group
000001-D99999	General metal or alloy group
F00001-F99999	Cast iron, carbon and low-alloy steel castings
G00001-G99999	Carbon and alloy steels (AISI and SAE)
H00001-H99999	H steels (AISI)
K00001-K99999	Other steels and ferrous alloys
S00001-S99999	Stainless steels
T00001-T99999	Tool steels

IV. Carbon steel

Classification	Characteristics	Typical uses
Low carbon	0.07%-0.15% carbon	Nails, iron bars and rods, auto bodies and pipes
Mild steel	0.15%-0.25% carbon	Gears, shafts, bolts, metal frames, angles and channels
Medium carbon	0.25%-0.60% carbon	Axles, shafts, machine bolts, boilers, hammers and sledges
High carbon	0.60%-1.50% carbon	Screwdrivers, crow bars, axes, springs, razors and fine cutters

V. Alloy steel

Classification	Characteristics	Typical uses
Nickel steel	Strong and hard; resists corrosion; withstands shocks, vibration, wear	Wire cables, railroad and car axles, and steel rails
Chromium steel	Fine grain; tough and strong; resists corrosion, shocks and scratches	Auto bearings and safes
High chromium steel (stainless steel)	Does not corrode; has a bright, silvery, attractive finish	Food service items subject to high standards of cleanliness
Chrome-nickel steel	Hard and strong	Auto gears, springs, axles and armor plate
Manganese steel	Tough and strong; can resist strain, shock and hammering	Jaws of rock crushers, chains, gears and safes
Molybdenum steel	Tough and strong, resists heat and impact wear	Auto parts, high-grade machinery and roller bearings
Tungsten steel	Hard, fine grained and resists heat	High-speed metal cutting tools
Tungsten steel (magnet steel)	Holds magnetism well	Electrical measuring instruments
Tungsten steel (tungsten carbide)	Hardest man-made metal	Cutting tools and dies
Vanadium steel	Tough, lightweight, fine-grained and resists shock	Auto axles, gears, springs
Stellite	Extremely hard	Heavy cutting tools
High-speed steel	Self-hardening steel	Cutting tools, taps and drills

VI. Iron

Classification	Characteristics	Typical uses
Wrought iron	Resists corrosion, withstands shock, is easy to bend (hot or cold)	Rivets, bolts, nails, horseshoes and ornamental iron
Gray cast iron	Relatively inexpensive and brittle with high compressive strength but low tensile strength	Large pipes, stoves, water hydrants and machinery frames
White cast iron	Very hard and brittle	Machine parts subjected to extreme wear or abrasion
Malleable cast iron	Tougher and more impact-resistant than other cast irons	Farm tools, implement parts and railroad equipment

IDENTIFYING FERROUS METALS

Match metals with characteristics and appearances.

____ 1.	Grayish-white, hard metallic element used instead of carbon to make special steels that are less brittle but harder than other steels with the same carbon content	a. Aluminum
____ 2.	Silvery-white, hard ductile (flexible) metallic element used to make special steels with increased strength, improved ductility and added toughness at low temperatures	b. Carbon
____ 3.	Silvery-white, hard metallic element used to make special steels that require increased hardness or strength in hot surface jobs	c. Chromium
____ 4.	Silvery-white metallic element used to make special steels with added tensile strength	d. Cobalt
____ 5.	Nonmetallic element added to iron to make steels that are harder and stronger	e. Copper
____ 6.	Steel-gray, brittle metallic element used for special hard steels in tool manufacturing	ab. Low, medium and high carbon steel
____ 7.	Hard, brittle nonmetallic element used to make special steels that are hard and brittle	ac. Manganese
____ 8.	Grayish-white, red-tinged nonmetallic element that is used to make special steels that are hard but less brittle	ad. Manganese steel
____ 9.	Hard, steel-gray element used to make steels subject to corrosive or high-temperature service	ae. Molybdenum
____ 10.	Dark gray when new; rusts with age and when stored outside	bc. Nickel
____ 11.	Dull-cast surface when new; rusts with age and when stored outside	bd. Silicon
____ 12.	Bright, silvery and smooth when new; some grades will rust and others tarnish	be. Stainless steel
____ 13.	Light gray and smooth; rusts rapidly in almost any environment	cd. Tungsten
____ 14.	Silvery-white with a smooth surface; highly rust and corrosion resistant except when alloyed with certain other elements; weighs much less than iron or steel	ce. Vanadium
____ 15.	Reddish-brown with a dull finish; highly subject to tarnishing	de. Wrought iron
____ 16.	White with a hard finish; good resistance to rust and corrosion	

Solve the following problems concerning systems for identifying steel.

17. In the designation AISI E 2512, the first "2" in the four-number digit indicates that the steel has nickel alloy. What does the "5" indicate?

18. Which of the following two identification numbers, AISI C 1020 and T00001, is from the Unified Numbering System?

INSTRUCTOR'S NOTE: Completion of this assignment sheet to specified score is the student's partial evaluation for competency L2.

ANSWERS TO ASSIGNMENT SHEET 1.1

1. c
2. bc
3. ae
4. ce
5. b
6. cd
7. bd
8. ac
9. d
10. ab
11. ad
12. be
13. de
14. a
15. e
16. bc
17. The percentage of nickel alloy
18. T00001

IDENTIFY SELECTED METALS BY APPEARANCE, COLOR AND CORROSION CHARACTERISTICS

Your instructor has tagged a group of metals with numbers. Name each metal by evaluating its appearance, color or any corrosion characteristics you can detect visually. Enter the name of the metal in the appropriate space below.

Metal #1:_____

Metal #2:_____

Metal #3:_____

Metal #4:_____

Metal #5:_____

Metal #6:_____

Metal #7:_____

NOTE: Your instructor may include other metals. In that case, extend your list as required.

INSTRUCTOR'S NOTE: Completion of this assignment sheet to specified score is the student's partial evaluation for competency L2.

MODULE: METALLURGY AND HEAT TREATING

UNIT II: IDENTIFYING METALS

LESSON 2: IDENTIFYING NONFERROUS METALS

I. Characteristics and uses of aluminum

A. Most used and most abundant of the nonferrous metals

B. Silvery-white metal with a brilliant surface beauty that resists corrosion and is maintenance-free

C. Very soft and difficult to use; usually combined with an alloy to change this characteristic

D. Good conductor of electricity; good thermal conductor

E. When polished, is an excellent reflector of heat

F. Malleable and ductile; can easily be formed into shapes or wires

G. Available in sheets, plates, bars, wires, pipes and tubes

H. Also available in a great number of extruded forms

II. AA system of identifying aluminum and aluminum alloys

A. Principal alloying ingredients are assigned numbers to assist with identification.

1. Aluminum, 99% or more with no alloy

2. Copper

3. Manganese

4. Silicon

5. Magnesium

6. Magnesium-silicon

7. Zinc

8. Other

B. The AA number code has a 1000 series (1000-1999) that is used only to identify unalloyed aluminum. The first digit indicates a minimum of 99% aluminum.

C. The second digit indicates the degree of impurity control during manufacture, with 0 as the low and 9 as the high.

D. The third and fourth digits indicate the aluminum purity in hundredths of a percent over 99%.

Example: In the number 1030, 1 indicates minimum 99% aluminum; 0 indicates minimum control of impurities; 30 indicates .30% beyond 99% or a product with 99.30% aluminum.

E. All series beyond 1999 (2000 and beyond) are used to identify aluminum alloys only.

F. The first digit of the upper series identifies the principal alloying element.

G. The second digit indicates purity control.

H. The third and fourth digits indicate the different types of alloys in the group.

Example: In the number 2017, 2 indicates that copper is the principal alloying element; 0 indicates minimum purity control; 17 indicates it is only aluminum and copper with no other alloying element.

III. AA temper designation system for aluminum

A. The AA temper designation system is based on basic treatments and processes used to produce different types of aluminum. The temper designation always follows the alloy and is separated by a dash.

Example: In the number 5083-H34, 5083 is the alloy designation and H34 is the temper designation.

B. The basic temper designations and subdivisions are as follows.

1. F--fabricated; indicates products that have acquired some uncontrolled tempering during manufacture

2. O--annealed (wrought products only), the softest temper

3. H--strain-hardened; indicates products that have had strength increased by strain-hardening or cold working with no thermal treatment to produce partial softening

4. T--thermally treated to produce stable tempers

NOTE: T1 through T10 indicates special treating and aging processes.

C. Heat treatment gives strength tempers and are listed as the second digit after the letter H.

D. Strength tempers are expressed on a base of 8, so that the number 2 would indicate 2/8 or 1/4 hard. The number 4 would indicate 4/8 or 1/2 hard. A 6 indicates 6/8 or 3/4 hard.

NOTE: The number 9 is also used to indicate 9/8 or extra hard.

E. UNS (Unified Numbering System)--system used by SAE and ASTM that uses a letter prefix with a five-digit number; letter usually suggests a general metal or alloy group

NOTE: This system has been proposed as an international system for identification of metals and alloys.

IV. Other aluminum abbreviations

A. AQ: aircraft quality

B. CQ: commercial quality

C. HTQ: high tensile quality

V. Steps in identifying aluminum

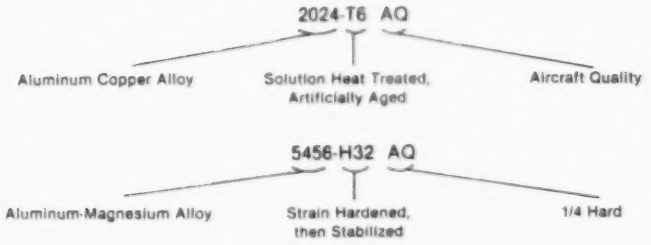
A. Determine number code series.

B. Determine the principal alloying element.

C. Determine the H or T designation.

D. Determine the hardness percentage.

E. Determine the quality designation.



VI. Chemical tests for identifying aluminum alloys

A. Copper, nickel, zinc test

1. Used to identify the more readily weldable alloys from the 2000 and 7000 series aluminum alloys

2. Consists of placing a drop of 20% sodium hydroxide on the surface of the alloy being tested after oxides have been removed from the base metal surface

3. If a black spot forms after 1-5 minutes, moderate to large amounts of copper, nickel and zinc are indicated.

B. Manganese test

CAUTION: This procedure produces toxic fumes.

1. Used to identify the more readily weldable alloys 3003 and 3004, which contain 1-1.5% manganese

2. Consists of preheating the aluminum to about 200F, placing a few drops of silver nitrate on the surface, then adding a few small crystals of ammonium presulfate

3. If the spot turns pink and stays pink as long as the aluminum is warm, a definite presence of manganese is indicated.

VII. Uses of other nonferrous metals

A. Copper is used in electric and telephone wires and alloyed with zinc or tin to form brass or bronze. For industrial applications, copper is the second best conductor of electricity.

B. Zinc is used to galvanize iron and steel for protection from rust

C. Magnesium is lightweight and has many varied uses.

D. Nickel is used primarily as an alloy to toughen steel

E. Titanium can be found in petrochemical applications because of its high corrosion resistance and in supersonic aircraft because of its high heat resistance and capacity to withstand vibration.

F. Beryllium has been used in the space program because of its light weight and high heat resistance.

G. Gold is used for jewelry, coins and coating electrical devices; it is usually alloyed with copper or nickel because it is too soft for general use.

H. Lead is found in auto batteries and is alloyed with tin to make solder.

I. Silver is the best conductor of electricity and is used in coins, jewelry, tableware and industrial applications.

J. Tin is used for making tin cans and as an alloy to make bronze, babbitt, pewter and solder.

ALUMINUM HARDNESS AND TEMPERING DESIGNATIONS

T#	Process	Applications
T1	Naturally aged to a substantially stable condition	Castings which have their strength increased by room-temperature aging from the as-cast condition
T2	Annealed cast products only	Castings which have their ductility improved and dimensional stability increased with an annealing treatment
T3	Solution heat-treated, then cold worked	Products cold worked to improve strength or to achieve the effect of cold work in flattening or straightening
T4	Solution heat-treated and naturally aged to a substantially stable condition	Products which are not cold worked after solution heat-treatment
T5	Artificially aged from the as-cast condition	Products which are aged at elevated temperatures from the as-cast condition to improve mechanical properties, dimensional stability or both
T6	Solution heat-treated, then stabilized	Products which are not cold worked after solution heat-treatment
T7	Solution heat-treated, then stabilized	Products which are stabilized to carry them beyond the point of maximum strength to provide control of special characteristics
T8	Solution heat-treated, cold worked, then artificially aged	Products which are cold worked to improve strength for certain applications
T9	Solution heat-treated, artificially aged, then cold worked	Products which are cold worked to improve strength for certain applications
T10	Artificially aged, then cold worked	Products which are artificially aged after an elevated-temperature, rapid-cool process, then cold worked to improve strength

IDENTIFYING NONFERROUS METALS

Solve the following problems concerning identification of aluminum and aluminum alloys.

1. Aluminum bearing any number code in the 1000 series would indicate what?

2. Aluminum bearing any number code in the 2000 series and beyond would indicate what?

3. In the number 5083-H34, the 5083 is the alloy designation, but what does the H34 designate?

4. Since strength tempers are expressed on a base of 8, what would the strength temper 8 designate?

Identify true statements with a T and false ones with an F.

____ 5. The copper, nickel, zinc test is used to identify the more readily weldable alloys from the 2000 and 7000 series aluminum alloys.

____ 6. Removing oxides from the base metal surface is an optional step when doing a copper, nickel and zinc test.

____ 7. If a black spot forms in 1-5 minutes after doing the copper, nickel and zinc test, moderate to large amounts of copper, nickel and zinc are present in the alloy.

____ 8. The manganese test consists of preheating the aluminum to about 200F, placing a teaspoon of silver nitrate on the surface, then adding a few small crystals of ammonium presulfate.

____ 9. If the spot turns blue and stays blue as long as the aluminum is warm, it indicates a definite presence of manganese.

____ 10. Zinc is used to galvanize iron and steel for protection from rust.

____ 11. Nickel is used primarily as an alloy to soften steel.

____ 12. Lead is used in auto batteries and alloyed with tin to make solder.

ANSWERS TO ASSIGNMENT SHEET 2.1

1. Unalloyed aluminum of 99% aluminum or more
2. Any aluminum alloy
3. The temper designation
4. 8/8 or full hard
5. T
6. F
7. T
8. F
9. F
10. T
11. F
12. T

MODULE: METALLURGY AND HEAT TREATING

UNIT II: IDENTIFYING METALS

LESSON 3: SPARK TESTING

I. Equipment requirements for spark testing

A. Stationary or portable power grinder

B. Medium-grit grinding wheel (40-60 grit)

C. Grinding wheel turning rate of 5,000 to 8,000 surface feet per minute

NOTE: An ideal turning ratio can be accomplished with an 8" diameter wheel turning at 3,600 rpm, but wheels of larger diameters can easily be used with proper rpm adjustment.

D. Grinding wheel that has been dressed to remove traces of glazing or metal particles left from previous grinding

II. Terminology used in spark testing (TM 3.1, 3.2)

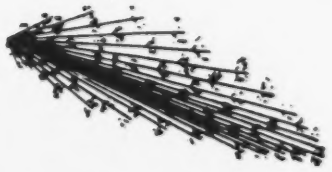
A. Arrow

B. Shaft

C. Fork

D. Sprigs

E. Stream



F. Color

1. Red at grinding wheel usually indicates cast iron.

2. Straw color at the end of the stream usually indicates cast iron.

3. Straw or light orange color at grinding wheel usually indicates low or high carbon steel.

4. White at grinding wheel usually indicates low or high carbon steel.

5. Orange usually indicates the presence of chromium.

G. Spark volume

1. None for nonferrous metals

2. Small amounts for gray cast iron and very small amounts for white cast iron

3. Moderately large volume for low carbon steel

4. Large amounts for high carbon steel

5. Moderate to large amounts for stainless steel, depending on type and amount of alloy

H. Length is the distance the spark pattern of stream travels from the grinding wheel.

SPARK TEST CHARACTERISTICS

Low-Carbon Steel

Color: white

Average length of stream with power grinder: 70 in.

Volume: moderately large

Shafts shorter than wrought iron and in forks and appendages

Forks become more numerous and sprigs appear as carbon content increases

Stainless and Other Alloy Steel

Color-white

Color: straw yellow

Stream length varies with type and amount of alloy content

Shafts may end in forks, buds or arrows, frequently with break between shaft and arrow. Few, if any, sprigs

High-Carbon Steel

Color: white

Average stream length with power grinder: 55 in.

Volume: large

Numerous small and repeating sprigs

SPARK TEST CHARACTERISTICS (CONT.)

White Cast Iron

Color: red

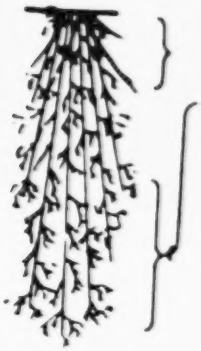
Color: straw yellow

Average stream length with power grinder: 20 in.

Volume: very small

Sprigs: finer than gray iron, small and repeating

Gray Cast Iron



Color: red

Color: straw yellow

Average stream length with power grinder: 25 in.

Volume: small

Many sprigs, small and repeating

SPARK TESTING

Place a T before true statements and an F before false ones.

____ 1. Red color at the grinding wheel usually indicates cast iron.

____ 2. Straw color at the stream's end usually indicates cast iron.

____ 3. Straw or light orange color at the grinding wheel usually indicates alloy steel.

____ 4. Green color at the grinding wheel usually indicates low or high carbon steel.

____ 5. Brown color usually indicates chromium presence.

____ 6. Nonferrous metals do not spark.

____ 7. Gray cast iron and white cast iron spark very little.

____ 8. Low-carbon steel spark testing produces a large volume of sparks with numerous small and repeating sprigs.

____ 9. Depending on type and amount of alloy, stainless steel sparks moderate to large amounts.

____ 10. Length is the distance the spark pattern of stream travels from the grinding wheel.

____ 11. In spark testing, a white color at the grinding wheel usually indicates low or high carbon steel.

____ 12. Ferrous metals do not give off sparks when spark tested.

ANSWERS TO ASSIGNMENT SHEET 3.1

1. T
2. T
3. F
4. F
5. F
6. T
7. T
8. F
9. T
10. T
11. T
12. F

CONDUCT SPARK TESTS

Equipment:

Safety glasses
Face shield
Locking pliers
Pedestal grinder
Metal samples, as selected by instructor

Procedure:	Evaluation 3 2 1 N
1. Check work area for safe working conditions. Provide a dark backdrop to assist with better spark recognition.	— — — —
2. Check grinder for proper working order. Check grinding wheel to make sure it has been dressed. Turn off light on grinder if there is one.	— — — —
3. Put on face shield. Lock pliers onto first metal sample.	— — — —
4. Turn on grinder and allow it to reach maximum rpm. Position yourself at the grinder so that all sparks will be free of obstructions and easy to observe.	— — — —
5. Place metal sample on tool rest. Hold pliers tightly and move metal into grinding wheel until it makes light contact. Grind metal sample long enough to produce a stable spark pattern.	— — — —
6. Observe: 1) color close to wheel, 2) color of sparks at the dying end of the spark stream, 3) shape of the spark pattern or stream pattern and 4) volume and length of spark stream.	— — — —
7. Remove metal sample and turn grinder off. Record your findings on the spark test identification chart.	— — — —

Metal Sample #	Color	Pattern Shape	Volume	Length in Inches	Name of Metal
1	At wheel: End Stream:				
2	At wheel: End Stream:				
3	At wheel: End Stream:				
4	At wheel: End Stream:				
5	At wheel: End Stream:				

8. Repeat the set-up, testing and recording procedure for additional metal samples, per your instructor. — — — —

9. Complete spark test identification chart and turn it in to your instructor for evaluation. — — — —

10. Secure all equipment. Clean up work area. Return tools and materials to proper storage area. — — — —

Average of above evaluations* — — — —

*This average is the student's final evaluation for competency L6.

MODULE: METALLURGY AND HEAT TREATING

UNIT II: IDENTIFYING METALS

UNIT TEST

Complete the following chart of metal classifications, characteristics and uses by using metals from the list below.

a. Chrome-nickel steel
b. Gray cast iron
c. High carbon
d. High chromium steel
e. High-speed steel
ab. Low carbon
ac. Malleable cast iron
ad. Manganese steel
ae. Medium carbon
bc. Mild steel
bd. Nickel steel
be. Stellite
cd. Vanadium steel
ce. White cast iron
de. Wrought iron

Classification	Characteristics	Typical uses
____ 1.	0.07-0.15% carbon	Nails, iron bars and rods, auto bodies and pipes
____ 2.	0.15-0.25% carbon	Gears, shafts, bolts, metal frames, angles and channels
____ 3.	0.25-0.60% carbon	Axles, shafts, machine bolts, boilers, hammers and sledges
____ 4.	0.60-1.50% carbon	Screwdrivers, crow bars, axes, springs, razors and fine cutters
____ 5.	Strong and hard; resists corrosion; withstands shocks, vibration and wear	Wire cables, railroad and car axles, steel rails
____ 6.	Does not corrode; has a bright, silvery finish that looks good	Sinks, tables and food service items subject to high standards of cleanliness
____ 7.	Tough but lightweight, fine grained, resists shock	Auto axles, gears and springs
____ 8.	Extremely hard	Heavy cutting tools
____ 9.	Self-hardening steel	Cutting tools, taps and drills
____ 10.	Resists corrosion; withstands shock; malleable, easy to bend hot or cold	Rivets, bolts, nails, horseshoes and ornamental iron
____ 11.	Relatively inexpensive, high compressive strength, low tensile strength, brittle	Large pipes, stoves, water hydrants and machinery frames

___ 12.	Very hard and brittle	Machine parts subjected to extreme wear or abrasion
___ 13.	Tougher and more impact-resistant than other cast irons	Farm tools, implement parts and railroad equipment

Select the option which best answers the question or completes the statement.

___ 14. Which of the following is not true of aluminum?

a. Aluminum is the most used but least abundant of the nonferrous metals.
b. Aluminum is a silvery-white metal with a brilliant surface beauty that resists corrosion and is maintenance free.
c. Pure aluminum is very soft and difficult to use so it is usually combined with an alloy to change its characteristics.
d. Aluminum is a good conductor of electricity.
e. None of the above

___ 15. Which is true of aluminum?

a. Aluminum is a good reflector of heat, especially when polished.
b. Aluminum is both malleable and ductile and can easily be formed into shapes or into wires.
c. Aluminum is available in sheets, plates, bars, wires, pipes and tubes.
d. Aluminum is also available in a great number of extruded forms.
e. All of the above

___ 16. Which is not an abbreviation used with aluminum?

a. Aircraft quality (AQ)
b. Commercial quality (CQ)
c. High tensile quality (HTQ)
d. United Numbering System (UNS)

___ 17. Which is not an equipment requirement for spark testing?

a. Stationary or portable power grinder
b. A medium-grit grinding wheel such as 40-60 grit
c. A grinding wheel turning rate with very low rpm
d. A grinding wheel that has been dressed to remove traces of glazing or metal particles left from previous grinding

Match other nonferrous metals with typical uses.

____ 18.	Used in electric and telephone wires and alloyed with zinc or tin to form brass or bronze.	*a.	Beryllium
____ 19.	Used to galvanize iron and steel for protection from rust	b.	Copper
____ 20.	Has many uses because it is lightweight	c.	Gold
____ 21.	Used primarily as an alloy to toughen steel	d.	Lead
____ 22.	Used in supersonic aircraft because of its high heat resistance and capacity to withstand vibration	e.	Magnesium
____ 23.	Utilized by the space program because of its light weight and high heat resistance	ab.	Nickel
____ 24.	Found in jewelry, coins and coating on electrical devices; usually alloyed with copper or nickel because of its softness	ac.	Silver
____ 25.	Used in auto batteries and alloyed with tin to make solder	ad.	Tin
____ 26.	The best conductor of electricity; used in coins, jewelry, tableware and in industrial applications	ae.	Titanium
____ 27.	Used for making tin cans and as an alloy to make bronze, babbitt, pewter and solder	bc.	Zinc

Arrange in order the steps in identifying aluminum.

____ 28.	First step	a.	Determine the quality designation
____ 29.	Second step	b.	Determine number code series
____ 30.	Third step	c.	Determine the H or T designation
____ 31.	Fourth step	d.	Determine the principal alloying element
____ 32.	Fifth step	e.	Determine the hardness percentage

Match metals with characteristics and appearances.

___ 33. Grayish-white, hard metallic element used instead of carbon to make special steels that are less brittle but harder than other steels with the same carbon content

___ 34. Silvery-white metallic element used to make special steels with added tensile strength

___ 35. Nonmetallic element added to iron to make steels that are harder and stronger

___ 36. Steel-gray, brittle metallic element used for special hard steels in tool manufacturing

___ 37. Silvery-white, hard ductile (flexible) metallic element used to make special steels with increased strength, improved ductility and added toughness at low temperatures

___ 38. Silvery-white, hard metallic element used to make special steels that require increased hardness or strength in hot surface jobs

___ 39. Hard, brittle nonmetallic element used to make special steels that are hard and brittle

___ 40. Dark gray when new; rusts with age and when stored outside

___ 41. Dull-cast surface when new; rusts with age and when stored outside

___ 42. Grayish-white, red-tinged nonmetallic element that is used to make special steels that are hard but less brittle

___ 43. Hard, steel-gray element used to make steels subject to corrosive or high-temperature service

___ 44. Bright, silvery and smooth when new; some grades will rust and others tarnish

___ 45. Silvery-white with a smooth surface; highly rust and corrosion resistant except when alloyed with certain other elements; weighs much less than iron or steel

___ 46. Light gray and smooth; rusts rapidly in almost any environment

___ 47. White with a hard finish; good resistance to rust and corrosion

___ 48. Reddish-brown with a dull finish; highly subject to tarnishing

a. Aluminum

b. Carbon

c. Chromium

d. Cobalt

e. Copper

ab. Low, medium and high carbon steel

ac. Manganese

ad. Manganese steel

ae. Molybdenum

bc. Nickel

bd. Silicon

be. Stainless steel

cd. Tungsten

ce. Vanadium

de. Wrought iron

ANSWERS TO UNIT TEST (L2)

1. ab
2. bc
3. ae
4. c
5. bd
6. d
7. cd
8. be
9. e
10. de
11. b
12. ce
13. ac
14. a
15. e
16. d
17. c (L6)
18. b
19. bc
20. e
21. ab
22. ae
23. a
24. c
25. d
26. ac
27. ad
28. b
29. d
30. c
31. e
32. a
33. c
34. ce
35. b
36. cd
37. bc
38. ae
39. bd
40. ab
41. ad
42. ac
43. d
44. be
45. a
46. de
47. bc
48. e

MODULE: METALLURGY AND HEAT TREATING

UNIT III: WORKING WITH METALS

UNIT OBJECTIVE

Upon completion of this unit, the student should be able to identify residual stresses, reasons for heating metals and ways to control distortion when welding. This knowledge will be evidenced by completion of the unit test to specified score.

SPECIFIC OBJECTIVES

After completion of the lessons in this unit, the student should be able to:

1.1 Select true statements concerning residual stresses.

1.2 Select true statements about causes of residual stresses and distortion.

2.1 Match heat applications with uses in weld quality control.

2.2 Identify methods of preheating and postheating.

2.3 Match types of steels with recommended preheat temperatures.

2.4 Match temperature-sensing devices with uses.

3.1 Complete statements concerning distortion control.

3.2 Identify restraining devices used to control distortion.

3.3 Practice the procedure for straightening a distorted steel member.

MODULE: METALLURGY AND HEAT TREATING

UNIT III: WORKING WITH METALS

CONTENTS OF THIS UNIT

A. Objective sheet

B. References

C. Notes to the instructor

D. Lesson plans

1. Lesson 1: RESIDUAL STRESSES

   a. Information outline

   b. Assignment sheet

      AS 1.1: Residual stresses

2. Lesson 2: HEAT APPLICATION

   a. Information outline

3. Lesson 3: CONTROLLING DISTORTION

   a. Information outline

   b. Assignment sheet

      AS 3.1: Prepare a working reference for straightening a distorted steel member

E. Unit test

F. Answers to unit test

REFERENCES

A. Book

1. Krar, Oswald and Amand. Technology of Machine Tools. New York: Gregg Division, McGraw-Hill Book Co., 1984.

B. Curriculum guide

1. Fortney, Clarence, and Mike Gregory. Introduction to Welding. Stillwater, Okla.: Mid-America Vocational Curriculum Consortium, Inc., 1984.

NOTES TO THE INSTRUCTOR

A. Suggested approaches to teaching this unit

1. Emphasize welder responsibility in this area, especially with new metals and corresponding heat treatment.

2. Give demonstrations that show preheating, finish welding, then post-heating and slow cooling in lime, sand or a furnace.

B. Suggested supplemental materials

1. Welding Supplementary Units. Columbia: Instructional Materials Laboratory, University of Missouri-Columbia, 1988.

MODULE: METALLURGY AND HEAT TREATING

UNIT III: WORKING WITH METALS

LESSON 1: RESIDUAL STRESSES

I. Residual stresses

A. Residual means "what is left at the end of a process." In welding, residual stresses are forces and counterforces that leave stress in a structure or part after a welding operation is completed.

B. Residual stresses can produce shrinkage and other forms of distortion that make parts difficult or impossible to fit-up.

C. Residual stresses can produce structural and metallurgical changes in base metals so severe that a welded assembly could fail, damaging property or hurting people.

D. Excessive residual stresses in a part or an assembly indicate that something in the welding procedure needs to be changed.

1. Joint design and fit-up

2. Welding process

3. Filler metals or base metals

4. Thermal or mechanical controls

a. Thermal controls include preheating, interpass heating and post-heating.

b. Mechanical controls include C-clamps, strongbacks, wedges and many types of restraining jigs and fixtures.

II. Causes of residual stresses and distortion

A. Filler metals and base metals in a welding procedure have to be heated to or near melting point. As they are heated, they expand--but not uniformly.

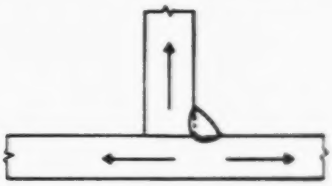
B. During and after the welding operation, filler metals and base metals contract as they cool--but not uniformly.

C. This lack of uniformity in expansion and contraction means that residual stresses will vary with joint design, welding procedure and metal type and thickness. The thicker the metals, the more problems there will be with residual stresses.

D. Once heat is applied, it has to go somewhere. The way heat escapes from a weld can be a clue to controlling residual stresses.

E. In a normal butt weld, heat escapes outward in both directions from the joint.

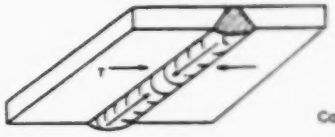
F. In a normal fillet weld, heat escapes outward from the sides and upward from the top.



Courtesy Lincoln Electric Company

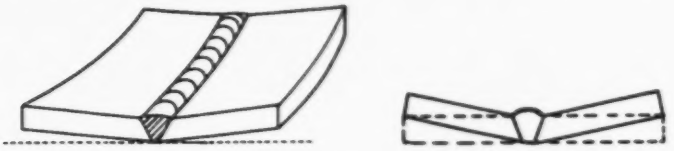
G. In a butt weld, the first passes can produce distortion down the length of the weld bead. This is called longitudinal stress.

H. As the first passes of a butt weld solidify, the movement across the weld bead is also restricted. This is called transverse stress.



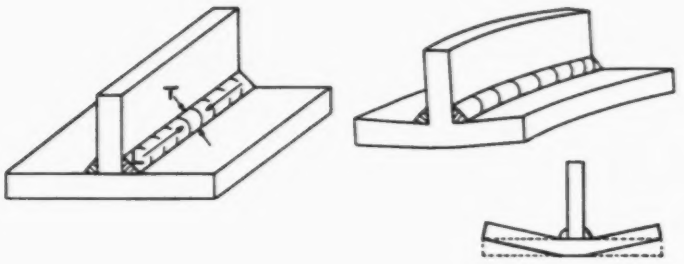
Courtesy Lincoln Electric Company

I. The combination of longitudinal and transverse stresses in a butt weld results in distortion that usually causes the plates to rise from a flat position to a slight angle.



Courtesy Lincoln Electric Company

J. In a fillet weld, the combination of longitudinal and transverse stresses not only causes a change from flat to a slight angle, but also can produce a roll or twist along the length of the parts.



Courtesy Lincoln Electric Company

RESIDUAL STRESSES

Place a T before true statements and an F before false ones.

____ 1. In welding, residual stresses refer to the forces and counter-forces that add stresses to a structure or part while a welding operation is in progress.

____ 2. Residual stresses can produce shrinkage and other forms of distortion that make parts difficult or impossible to fit-up.

____ 3. Residual stresses can produce structural and metallurgical changes in base metals so severe that a welded assembly could fail.

____ 4. Excessive residual stresses in a part or an assembly indicates that something in the welding procedure needs to be changed.

____ 5. As filler metals and base metals in a welding procedure are heated to or near melting point, they expand uniformly.

____ 6. During and after the welding operation, filler metals and base metals contract uniformly as they cool.

____ 7. The way heat escapes from a weld can be a clue to controlling residual stresses.

____ 8. In a normal butt weld, heat escapes outward in both directions from the joint.

____ 9. In a normal fillet weld, heat escapes outward from the sides and downward.

____ 10. In a butt weld, the first passes can produce distortion down the length of the weld bead. This is called transverse stress.

____ 11. As the first passes of a butt weld solidify, the movement across the weld bead is also restricted. This is called longitudinal stress.

____ 12. In a fillet weld, the combination of longitudinal and transverse stresses not only causes a change from flat to a slight angle, but also can produce a roll or twist along the length of the parts.

ANSWERS TO ASSIGNMENT SHEET 1.1

1. F
2. T
3. T
4. T
5. F
6. F
7. T
8. T
9. F
10. F
11. F
12. T

MODULE: METALLURGY AND HEAT TREATING

UNIT III: WORKING WITH METALS

LESSON 2: HEAT APPLICATION

I. Weld quality control by heat

A. Heat applications and uses

1. Preheating a part before the welding process helps control cracking, stresses from shrinkage and promotes a slower cooling rate to prevent excessive hardening.

2. Interpass heat between welding passes helps maintain preheat temperature.

NOTE: The welding process itself will usually provide sufficient interpass heat, but on large assemblies, heating with a torch between passes is required to maintain proper welding temperatures.

3. Postheating a part after the welding process and allowing it to cool slowly promotes stress relief in the weldment and the base metal.

B. Situations where preheating is usually required

1. When large or bulky parts are being welded or when parts being welded have a complicated shape

2. When the atmospheric temperature is cold or the temperature of the parts is cold

3. When the carbon or alloy content of steel is high

4. When the welding speed is fast

5. When small-diameter welding rods are used

II. Methods of preheating and postheating

A. Furnaces

B. Electrical strip heaters clamped parallel to joints about 6" from the seam

C. Acetylene, propane or oil torches used singly or in banks

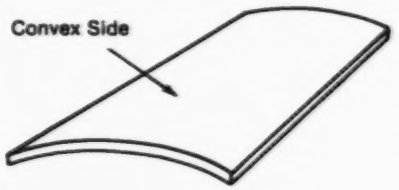
D. Torch heating uses 1) multiflame heads or rosebuds or 2) natural gas with compressed air and a single-orifice heating tip the same size that would be used to oxy-acetylene weld the joint.

NOTE: The second method is used frequently in shop work because it gives a hot flame that burns clean and helps avoid contamination of the weld zone.

1. **Spot heating** is applied at one specific point so that cooling will cause a slight inward movement around the point and help control nondirectional distortion.

2. **Slot heating** is applied along a seam or perpendicular to a seam to control directional distortion.

3. When attempting to flatten plates, apply spot or slot heating to the **convex** side since the side where heat is applied always shortens more than the other side.



III. Types of steels and recommended preheat temperatures

A. With mild steels, preheating is not normally required. However, if the temperature is below 50F and the plate thickness is more than 1", preheat to about 100F or higher.

B. With medium carbon steels, preheat from 200-400F. Retain the same interpass temperature. Postheating is recommended, especially on thicker sections.

C. On high carbon steels, preheat and interpass temperatures should be a minimum of 400F. Postheating is recommended, especially on thicker sections.

IV. Temperature-sensing devices

A. Pyrometers are portable thermometers specifically designed to measure surface heat.

B. Thermocouples are temperature-sensing devices that may be attached to the work but are more often used in heating ovens and postweld heat treatment.

C. Crayons and pellets are temperature-sensing devices that melt suddenly when the work reaches a specific temperature.

NOTE: Crayons are usually color-coded for specific temperatures and are frequently used in pairs to indicate the heating range so that desired temperatures can be more accurately determined.

MODULE: METALLURGY AND HEAT TREATING

UNIT III: WORKING WITH METALS

LESSON 3: CONTROLLING DISTORTION

I. Ways to control distortion in welding

A. Do not overweld.

1. The more metal that is placed in a joint, the greater the shrinkage forces.

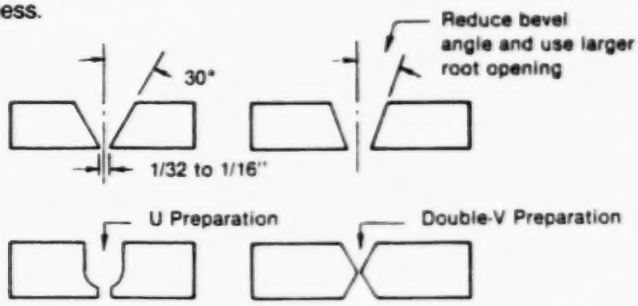
2. Excess weld metal does not increase weld strength, but it does increase shrinkage forces.

B. Modify edge preparation and fit-up when butt welding thicker metals

1. Plates for butt welds on thinner metals provide good fusion and require minimum weld metal.

2. For thicker plates, decrease the bevel angle and increase the root opening or use a J or U design.

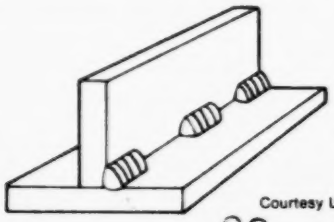
3. A double V-joint requires about half the weld metal of a single V-joint for the same plate thickness.



C. Use intermittent welding

1. Intermittent welds provide needed strength

2. Intermittent welds reduce the amount of weld metal required.



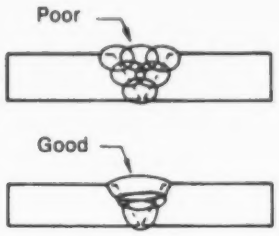
Courtesy Lincoln Electric Company

D. Use as few passes as possible.

1. Each pass increases the possibility for increased shrinkage.

2. Fewer passes with larger electrodes are better than more passes with smaller electrodes.

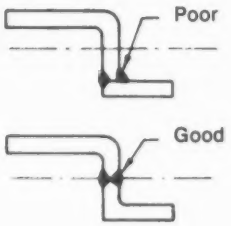
NOTE: Suggestions about fewer passes apply only to situation were fewer passes would not violate specifications.



E. Place welds near a neutral axis.

1. Weld design and weld sequence can both help control shrinkage.

2. Welding at or along a neutral axis gives less leverage to forces that cause distortion.



Courtesy Lincoln Electric Company

F. Use backstep welding.

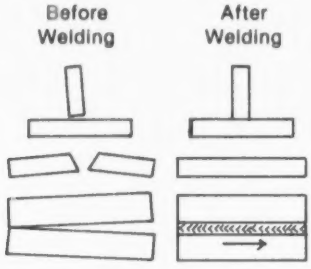
1. Direction of welding is usually left to right, but beads deposited from right to left so that heat will spread uniformly to outer edges should bring plates back in alignment.

2. Backstep welding is not an economical procedure for automatic welding.

G. Preset parts to take advantage of shrinkage.

1. Anticipate the places of shrinkage and amount of shrinkage. Position parts so that they will be pulled into alignment during welding.

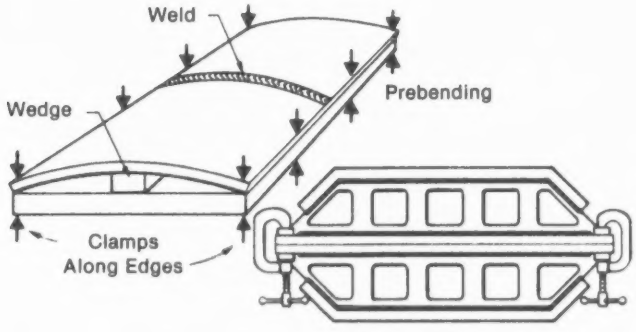
2. The process requires good estimating, but a few trial welds should indicate how to preset the parts.



H. Prebend and clamp parts or clamp parts back to back

1. Prebending actually makes the joint longer so that shrinkage will cause the joint to be flat as the plate cools and the clamps are released.

2. Clamping similar parts back to back helps distortion forces work against each other to control shrinkage.

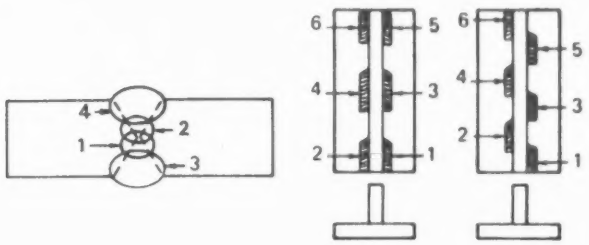


Back-to-Back Clamping

I. Weld in a logical sequence.

1. Weld at different points in the assembly so that as the part shrinks in one place, it counteracts the shrinkage forces of previously made welds.

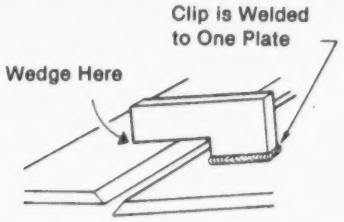
2. Alternate sides on fillet welds and use intermittent welding so that shrinkage in the first weld is counterbalanced by shrinkage in the second weld, etc.



Courtesy Lincoln Electric Company

II. Ways to control distortion with restraining devices

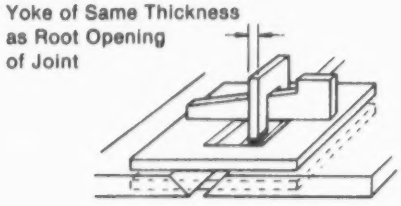
A. When butt welding plates, tack weld clips along the edge of one plate, then drive wedges under the open side of the clip to force the edges into alignment.



Courtesy Lincoln Electric Company

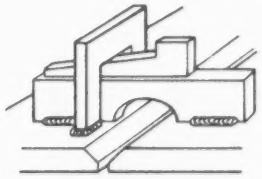
B. Tack weld a yoke to a backup strip. Slip the yoke between the edges, then place a guide yoke on top of the plates, driving a wedge through the first yoke to align the plates.

NOTE: When yoke thickness is the same as the root opening, it can be moved along to serve as a spacer between the edges.



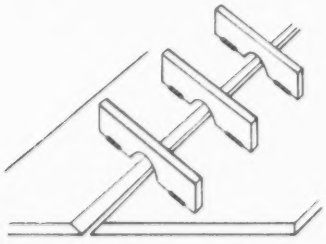
Courtesy Lincoln Electric Company

C. For butt welds on thicker plates, tack weld a yoke on top of one plate, a bar to the top of the second plate, then drive a wedge between the yoke and the bar.



Courtesy Lincoln Electric Company

D. When there is a possibility that several strongbacks would restrain the weld so much that cracking results as the weld cools, position the strongbacks at a 45-degree angle across the joint to allow transverse movement.



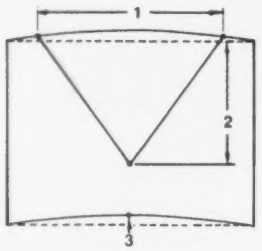
Courtesy Lincoln Electric Company

E. Guidelines for correcting distortion in welded components

1. Determine width of distortion at maximum point.

2. Determine length of distortion.

3. Determine out-of-tolerance amount in inches or fractions of an inch.



1. Length
2. Width
3. How Much Out

4. Sketch dimensions to use as a work reference.

III. Procedure for straightening a distorted steel member

A. Determine dimensions of needed correction.

B. Mark work area and dimensions with a soapstone so that point C is situated a distance equal to one third the width of the member from point A.

C. Start heat at point C with flame pointing toward point B.

NOTE: Flame angle must be toward point B to keep point A as cool as possible, causing point C to "upset" or expand into itself.

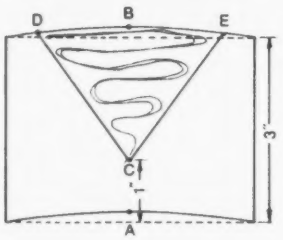
D. Heat point C to a light red, but not enough to melt the surface.

E. As point C turns a light red, move the flame slowly toward point B as you widen the heating pattern by moving the torch in a circular motion toward the extremes of points D and E.

F. As the flame moves from point C, the metal at that point cools and "upsets" or expands into itself.

G. The widening heat pattern, plus the cooling and contraction of the metal behind it, will cause the edge at B to stretch, then contract and straighten the member.

NOTE: The secret for successfully completing this procedure is to keep point A as cool as possible so it acts as a hinge around which the out-of-tolerance points can move.

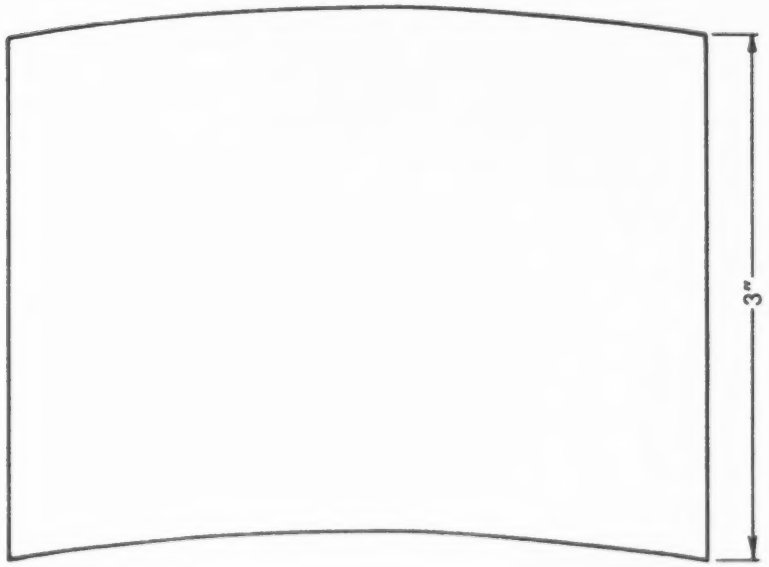


PREPARE A WORKING REFERENCE

FOR STRAIGHTENING A DISTORTED STEEL MEMBER

Use a pencil and a rule to measure and mark on the following illustration the critical heating points and pattern for straightening an out-of-tolerance steel member, based on the following information.

1. The steel member is 3" wide.
2. The width of the distortion at maximum point is 3".
3. The length of distortion is 2".
4. The maximum distortion is at the top of the member (as shown) and near the center of the span.
5. All critical points should be labeled with a letter and the heating pattern should be sketched in as a working reference.



MODULE: METALLURGY AND HEAT TREATING

UNIT III: WORKING WITH METALS

UNIT TEST

Choose the option which best answers the question or completes the statement.

____ 1. What is a good way to control distortion in welding?

a. Do not overweld.
b. Modify edge preparation and fit-up when butt welding thicker metals.
c. Use intermittent welding.
d. Make as few passes as possible.
e. All of the above

____ 2. Which is <u>not</u> a recommended method of controlling weld distortion?

a. Place welds near a neutral axis.
b. Use backstep welding.
c. Prebend and clamp parts or clamp parts back-to-back.
d. Weld in a logical sequence. Finish one side of a fillet weld before advancing to the other side.

____ 3. What type of restraining device is used to control distortion?

a. Clips and wedges
b. Yokes
c. C-clamps
d. Strongbacks
e. All of the above

____ 4. When there is a possibility that the use of several strongbacks would restrain the weld so much that it would produce cracking as the weld cools, position the strongbacks at a ___-degree angle across the joint to allow transverse movement.

a. 90
b. 60
c. 45
d. 30

____ 5. Which is <u>not</u> a guideline for correcting distortion?

a. Determine width of distortion at maximum point.
b. Determine length of distortion.
c. Determine out-of-tolerance distortion in inches or fractions of an inch.
d. There is no need to sketch dimensions, but do keep a good mental picture of the problem to use as a work reference.

___ 6. Preheating and postheating methods do not include which of the following?

a. Furnaces
b. Electrical space heaters clamped parallel to joints about 3" from the seam
c. Acetylene, propane or oil torches used singly or in banks
d. Torch heating using multiflame heads or rosebuds

___ 7. For _____ steel, preheat at 200-400F. Retain the same interpass temperature. Postheating is recommended, especially on thicker sections.

a. Medium carbon
b. High carbon
c. Mild
d. Low carbon

___ 8. Preheat and interpass temperatures should at least 400F for _____ steels. Postheating is recommended, especially on thicker sections.

a. Medium carbon
b. High carbon
c. Mild
d. Low carbon

___ 9. Which is the false statement?

a. A double V-joint uses about half the weld metal of a single V-joint for the same thickness.
b. To control distortion, fewer passes with larger electrodes are better than more passes with smaller electrodes.
c. Backstep welding is an economical procedure for automatic welding.
d. Weld at different points in the assembly so that as the parts shrink in one place, they counteract the shrinkage forces of welds already made.
e. None of the above

Match the heating term on the right with its definition.

____ 10. Heating a part before the welding process starts

____ 11. Heating between welding passes to maintain the preheat temperature

____ 12. Heating a part after the welding process and allowing it to cool slowly

____ 13. Heat applied at one specific point

____ 14. Heat applied along a seam or perpendicular to a seam to control
directional distortion

____ 15. Spot and slot heating should be applied on the opposite side when attempting to flatten plates.

____ 16. Portable thermometers specifically designed to measure surface heat

____ 17. Temperature-sensing devices that may be attached to the work, but more often used in heating ovens and postweld heat treatment

____ 18. Temperature-sensing devices that melt suddenly when the work reaches a specific temperature

a. Convex heating

b. Crayons and pellets

c. Interpass heat

d. Postheat

e. Preheat

ab. Pyrometers

ac. Slot heating

ad. Spot heating

ae. Thermocouples

19. List three situations where preheat is usually required.

a.

b.

c.

NOTE: Completion of this test to specified score is the student's final evaluation for competency L3: Identify and apply principles of preheating and postheating.

ANSWERS TO UNIT TEST (L3)

1. e
2. d
3. e
4. c
5. d
6. b
7. a
8. b
9. c
10. e
11. c
12. d
13. ad
14. ac
15. a
16. ab
17. ae
18. b

19. Any three of the following:

    a. When large or bulky parts are being welded or when parts being welded have a complicated shape
    b. When the atmospheric temperature is cold or the temperature of the parts is cold
    c. When the carbon or alloy content of steel is high
    d. With rapid welding speeds
    e. When small-diameter welding rods are used